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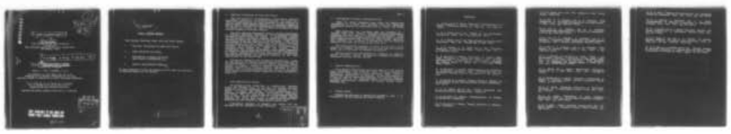

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6 LASER AND OPTICAL PHYSICS,

by

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9 Final Report, 1 Aug 72-1 Nov 75,

Good FC

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The findings in this report are not to be construed as an official department of the Army position, unless so designated by other authorized documents.

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CONTENTS:

LASER & OPTICAL PHYSICS

This contract concerned itself with four major topics:

1 Nonlinear Interaction of Light with Matter,

2 Laser Operation and Design,

3 Fluctuations in Lasers and Matter Near Points of Instability, and

4 Quantum Communications Theory.

We shall summarize briefly the progress made in each area referring to published papers for the details.

1. Nonlinear Interaction of Light with Matter.

This work started [1] by formulating a rotationally invariant macroscopic description of dielectric crystals. One result was a theory of photoelasticity [2] which predicted [3] that rotations as well as strains would generate changes in the dielectric tensor and scatter light. Experimental investigations of Brillouin scattering in calcite and rutile [4] then verified the existence of these hitherto unexpected rotational effects.

The above mentioned experiments required absolute measurements of Brillouin scattering intensities. It was necessary to relate theoretical results inside the crystal to measurements outside. For this purpose, a new Green's function theory for electromagnetic radiation in anisotropic crystals [5] was developed. (The theory was extended to the case when the source was inside the crystal and receiver outside [6].) The results were also applied to Raman scattering by polaritons [6]. This permitted a wave calculation of intensity ratios outside and inside the crystal. These calculations were verified and extended to more general geometries by geometrical optics calculations of the solid angle magnification and source demagnification [7] that takes place at an arbitrarily oriented crystal surface, with arbitrary directions of the light rays relative to the crystal axes.

The work on dielectrics was extended to pyroelectrics. Linear [8] and nonlinear [9] theories were developed on the interaction of the electromagnetic field with elastic, optical phonon and exciton degrees of freedom. Maxwell's equations were formulated in the material reference frame including boundary conditions at moving surfaces [10]. A detailed analysis was also made of the asymmetric stress tensor and stress boundary conditions in moving pyroelectric media [11].

2 Laser Operation and Design.

The problem of mode competition in homogeneously broadened lasers was analysed [12]. It was shown that confocal resonator geometries led to the fundamental mode becoming unstable at high powers. To obtain high powers, and high directionality, it is necessary to suppress off-axis modes. Two schemes for suppression were given. One was based on the use of interferences with the help of extra curved mirrors [13]. A second scheme involved enlarging the active mode volume by using convex mirrors [14]. Stability was then achieved by adding concave curved rims.

A systematic treatment of paraxial wave optics [15] was developed for the treatment of laser amplifiers.

3. Fluctuations in Lasers & Condensed Matter.

Among the topics considered were third and higher-order correlations in a laser near threshold [16]. Our theory was subcequently confirmed by experimental work of Chopra and Mandel [17].

Mode competition was considered near the threshold of a two-mode laser [18]. Recently developed efficient computational techniques [19] have aided in the solution of this problem. Laser models have also been attacked, using the same technique, by direct use of density matrices [20] rather that Fokker-Planck equations. This permitted the treatment of fluctuations when the number of photons in the laser can be arbitrarily small [21].

The same techniques applicable to lasers have also been found useful in studying hydrodynamic instabilities [22] near critical points such as the Benard and Rayleigh instabilites.

Similar methods were also employed in studying the relation between radiative reaction and zero-point fluctuation effects in spontaneous emission problems [23,24].

4. Optical Communications.

In an optical communication system for which $h\nu \gg kT$, quantum noise predominates over classical noise. The usual theorems of communication theory require revision since they assume arbitrary simultaneous measurements are possible. We have made progress in dealing with optimum estimation procedures [25] including obtaining a quantum form of the Cramer-Rao bound. We have also obtained necessary and sufficient conditions for optimum digital signal detection [26].

5. Current topics.

Progress has been made in applying the methods in part 1 to ferromagnets, antiferromagnets and liquid crystals.

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